TITLE OF THE INVENTION

CONTROLLER OF VACUUM PUMP

BACKGROUND OF THE INVENTION

The present invention relates to a controller of a vacuum pump having a pump mechanism section that performs evacuation to set a space to be evacuated to a predetermined degree of vacuum, and an electric motor section for driving the pump mechanism section.

There is known a semiconductor production apparatus of a type that has a load-lock chamber provided side-by-side with respect to a process chamber that performs film deposition and other processes to a wafer (substrate) as described in, for example, Japanese Patent Laid-Open Publication No. 9-306972.

This apparatus performs wafer exchange between the process chamber and the semiconductor production apparatus exterior via the load-lock chamber. A vacuum pump that sets the load-lock chamber to a predetermined degree of vacuum is connected via a valve to the load-lock chamber. This valve is designed in such a way as to be able to connect or disconnect the load-lock chamber to or from the vacuum pump in terms of pressure when it is externally manipulated.

Wafer exchange between the load-lock chamber and the process chamber is carried out under a state where the load-lock chamber is disconnected from the semiconductor production apparatus exterior in terms of pressure, and is set to a predetermined degree of vacuum by the vacuum pump. Wafer exchange between the load-lock chamber and the semiconductor production apparatus, on the other hand, is carried out under a state where the load-lock chamber is disconnected from the

process chamber in terms of pressure and is set back to the atmospheric pressure.

Work efficiency in semiconductor production is improved by performing film deposition and other processes in the process chamber disconnected from the load-lock chamber in terms of pressure while wafer exchange between the load-lock chamber and the semiconductor production apparatus exterior is executed.

At the time of depressurizing the load-lock chamber under atmospheric pressure to a predetermined degree of vacuum again, the load-lock chamber is connected to the vacuum pump by setting the valve to an open state from the closed state and then the load-lock chamber is evacuated. At this time, in the case where the valve is switched to the open state from the closed state while the vacuum pump is driven, the pressure in the vacuum pump suddenly increases to atmospheric pressure from the predetermined degree of vacuum, abruptly increasing the pressure load (pressure load associated with evacuation) of the vacuum pump. When an electric motor is used as the drive source for the vacuum pump, the abrupt increase in pressure load quickly increases the output torque of the electric motor or the load torque of the vacuum pump.

One way to prevent the components of the vacuum pump from being damaged by the sudden increase in load torque of the vacuum pump is to control the electric motor using a controller in such a way that the load torque of the vacuum pump does not exceed a predetermined upper limit. The time charts in Figs. 2(a) and 2(b) show examples of the mode of the control. A broken line 91 in Fig. 2(a) indicates the drive frequency when a synchronous motor type brushless motor is used as the electric motor. A broken line 92 in Fig. 2(b) indicates the value of a current supplied to the electric

motor. The current value correlates with the size of the output torque of the electric motor section or the load torque of the vacuum pump.

When the valve is switched to the open state from the closed state at time t1, as shown in Figs. 2(a) and 2(b), the abrupt increase in pressure load of the vacuum pump caused by the switching rapidly increases the value of the current supplied to the electric motor. That is, the load torque of the vacuum pump rapidly increases.

When the controller determines that the current value of the electric motor has reached a predetermined upper limit i2 at time t2, it rapidly reduces the drive frequency of the electric motor toward a drive frequency fmin on the low-speed side of the rotational speed of the electric motor from a drive frequency fmax on the high-speed side. The reduction in drive frequency lowers the rotational speed of the electric motor, thereby suppressing an increase in pressure load of the vacuum pump. This restricts the output torque of the electric motor or the load torque of the vacuum pump so that the torque does not exceed a predetermined upper limit, i.e., the upper limit of a torque corresponding to the upper limit i2 of the supply current.

Although the aforementioned control mode prevents the components of the vacuum pump from being damaged by an excess increase in load torque of the vacuum pump, a rapid rise in load torque occurs when the closed state of the valve is switched to the open state. At this time, an increased speed in load torque differs significantly between the before and after time t1 at which the rise has started, i.e., an abrupt upward change in the increased speed of the load torque, and the state at which the increased speed is great, continues until the current value of the electric motor reaches the

predetermined upper limit i2.

Even if the control mode prevents an excess increase in load torque of the vacuum pump, therefore, the components of the vacuum pump may be shocked significantly by an abrupt upward change in the increased speed of the load torque or continuation of the state at which the increased speed is great after the upward change. This causes the components of the vacuum pump to be damaged.

To prevent the components of the vacuum pump from being damaged, the components may be reinforced to be stronger. This however, undesirably leads to enlargement and weight increase of the vacuum pump.

Accordingly, it is an object of the present invention to provide a controller of a vacuum pump that can improve the durability of the vacuum pump without size enlargement or weight increase that may originate from reinforcement of the vacuum pump.

SUMMARY OF THE INVENTION

To achieve the objects, according to one aspect of the invention, there is provided a controller of a vacuum pump, which performs deceleration control to decrease the rotational speed of an electric motor section when an increase in load torque of the vacuum pump per unit time abruptly changes upward.

In the case where with the vacuum pump activating, the outside air is led into the space to be evacuated so that the pressure in the space rapidly rises, for example, as the pressure torque of the vacuum pump (pressure load associated with evacuation) increases, the output torque of the electric

motor section, i.e., the load torque of the vacuum pump tends to rise. In this case, the increase in load torque of the vacuum pump per unit time (increased speed of the load torque of the vacuum pump) may change upward from the state where it is nearly zero to the state where it exceeds a certain level. In other words, the increase in load torque of the vacuum pump per unit time may rapidly change upward.

The controller of the present invention performs deceleration control to decrease the rotational speed of the electric motor section when an increase in load torque of the vacuum pump per unit time abruptly changes upward. This reduces shocks applied to the components of the vacuum pump by the abrupt upward change in the increase in load torque of the vacuum pump per unit time or the continuous state where the increase in load torque of the vacuum pump per unit time is large after the upward change of the load torque when the load torque rises. It is therefore unnecessary to reinforce the components of the vacuum pump in order to improve the shock resistance, thereby preventing a reinforcement-originated size increase or weight increase of the vacuum pump.

According to this aspect of the invention, it is possible to more accurately grasp how much the increase in load torque of the vacuum pump per unit time has changed in a predetermined time, as compared with the mode that carries out deceleration control based on the increase in load torque of the vacuum pump per unit time. In this specification, the "rate of change in the increase in load torque of the vacuum pump per unit time" represents how much the increase in load torque of the vacuum pump per unit time has changed per unit time.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram of a semiconductor production apparatus and a vacuum pump;

Fig. 2(a) is a time chart showing the drive frequency in an electric motor section and Fig. 2(b) is a time chart showing the current value in the electric motor section; and

Figs. 3(a) and 3(b) show time charts in another embodiment, Fig. 3(a) being a time chart showing the drive frequency in an electric motor section, while Fig. 3(b) is a time chart showing the current value in the electric motor section.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

One embodiment of the invention as embodied in a vacuum pump for evacuating a load-lock chamber in a semiconductor production apparatus is described below with reference to the accompanying drawings.

As shown in Fig. 1, a process chamber 12 is provided side-by-side with respect to a load-lock chamber 13 in a semiconductor production apparatus 11. Deposition processes, such as vacuum deposition or sputtering on a wafer, are carried out in the process chamber 12. Those processes are executed after the process chamber 12 is set to a predetermined degree of vacuum by using an unillustrated evacuation system.

Wafer exchange between the exterior (atmospheric pressure space) of the semiconductor production apparatus 11 and the process chamber 12 is carried out via the load-lock chamber 13. That is, a passage for exchanging a wafer at the time of wafer exchange is provided between both chambers 12 and 13 and a gate valve 14 that connects and disconnects both chambers 12 and 13 to and from each other in terms of pressure is provided in that passage. Further, the semiconductor production

apparatus 11 is provided with a passage for wafer exchange between the load-lock chamber 13 and the exterior of the semiconductor production apparatus 11, and a gate valve 15 that connects and disconnects the load-lock chamber 13 and the exterior to and from each other in terms of pressure is provided in that passage.

A vacuum pump 20 is connected to the semiconductor production apparatus 11 via an exhaust passage 16. The vacuum pump 20 evacuates the load-lock chamber 13 as a space to be evacuated. A first valve 17, which connects and disconnects the load-lock chamber 13 and the vacuum pump 20 to and from each other in terms of pressure when manipulated externally, is provided in the exhaust passage 16.

The load-lock chamber 13 is communicated with the exterior of the semiconductor production apparatus 11 via an outside-air inlet passage 18. A second valve 19, which can connect and disconnect the load-lock chamber 13 and the exterior to and from each other in terms of pressure when manipulated externally, is provided in the outside-air inlet passage 18.

The vacuum pump 20 has a pump mechanism section 21 that evacuates the load-lock chamber 13 to set the chamber 13 to a predetermined degree of vacuum and an electric motor section 22 for driving the pump mechanism section 21. The electric motor section 22 is comprised of a synchronous motor type brushless motor, specifically a brushless DC motor, and is driven by power supplied from an inverter 30 that constitutes the controller. The rotational speed of the electric motor section 22 is adjusted by adjusting the drive frequency (rotational-speed instruction value) in the supply current from the inverter 30.

In this embodiment, the electric motor section 22 is driven by a steady voltage by the inverter 30 and the value of the supply current to the electric motor section 22 correlates with the magnitude of the output torque of the electric motor section 22, i.e., the load torque of the vacuum pump 20.

The inverter 30 has an electronic control unit (ECU) 31 equipped with a microcomputer and a current detector 32. The ECU 31 and the current detector 32 constitute motor control means. The current detector 32 detects the value of the supply current to the electric motor section 22 and provides the ECU 31 with the detected information. The current detector 32 constitutes detection means that detects the value of the supply current to the electric motor section 2. The ECU 31 adjusts the drive frequency in the supply current to the electric motor section 22 based on the detected information provided by the current detector 32.

The ECU 31 computes the output torque of the electric motor section 22 or the load torque of the vacuum pump 20 based on the detected information from the current detector 32, i.e., the value of the supply current to the electric motor section 22. Based on the load torque, the ECU 31 computes an increase in load torque of the vacuum pump 20 per unit time (which hereinafter is referred to as the increased speed of the load torque of the vacuum pump 20 for the sake of convenience). The ECU 31 repeatedly monitors the increased speed of the load torque of the vacuum pump 20 at a predetermined time interval.

When the ECU 31 determines that the increased speed of the load torque of the vacuum pump 20 is greater than a predetermined value, the ECU 31 determines that there has been an abrupt upward change in the increased speed of the load torque of the vacuum pump 20. Having made this decision, the

ECU 31 changes the drive frequency in the supply current to the electric motor section 22 to the low-speed side of the rotational speed of the electric motor section 22, i.e., reduces the drive frequency, in order to decrease the increased speed of the load torque of the vacuum pump 20. This control is referred to as deceleration control.

The ECU 31 keeps monitoring the increased speed of the load torque of the vacuum pump 20 even after it has decided that the increased speed of the load torque of the vacuum pump 20 abruptly changed upward. More specifically, the ECU 31 in this embodiment continuously and repeatedly performs the aforementioned speed monitoring as long as the ECU 31 is in operation. When the ECU 31 decides through the monitoring that the increased speed of the load torque of the vacuum pump 20 has abruptly changed upward, the ECU 31 executes the deceleration control and maintains the drive frequency, which has been reduced by the control, until the next timing at which it determines whether the increased speed is greater than a predetermined value.

In the case where the ECU 31 has decided that the increased speed of the load torque of the vacuum pump 20 abruptly changed upward, the ECU 31 repeatedly executes the deceleration control unless a process that has a priority over the deceleration control is performed. One process that has a priority over the deceleration control is a process of adjusting the value of the supply current to the electric motor section 22 in such a way as not to exceed an upper limit i2. This process will be discussed later.

The action of the vacuum pump 20 with the above-described structure is discussed next referring to the time charts in Figs. 2(a) and 2(b). A solid line 51 in Fig. 2(a) indicates the drive frequency in the supply current to the electric

motor section 22. A solid line 52 in Fig. 2(b) indicates the value of the supply current to the electric motor section 22 of this embodiment.

Work for wafer exchange between the process chamber 12 and the load-lock chamber 13 is carried out under a state where the load-lock chamber 13 is set to the same predetermined degree of vacuum as the process chamber 12 by the vacuum pump 20 and the gate valve 14 is open. At this time, the gate valve 15 and the second valve 19 are closed.

Work for wafer exchange between the load-lock chamber 13 and the outer space of the semiconductor production apparatus 11 is carried out under a state where, with the gate valves 14 and 15 closed, the second valve 19 is opened to set the load-lock chamber 13 to the same pressure as that of the exterior space (atmospheric pressure) and the gate valve 15 is then opened. At this time, the first valve 17 is closed.

At the time the load-lock chamber 13 is set to a predetermined degree of vacuum by the vacuum pump 20 after a wafer is loaded into the load-lock chamber 13 for example, the first valve 17 is opened with the vacuum pump 20 or the electric motor section 22 driven, thereby starting evacuation of the load-lock chamber 13. Time t1 in Figs. 2(a) and 2(b) indicates the timing at which the first valve 17 is opened, and until which the ECU 31 has driven the electric motor section 22 with the drive frequency fmax on the high-speed side of the rotational speed of the electric motor section 22.

Before time t1, the first valve 17 is closed so that the pressure load of the vacuum pump 20 associated with the evacuation is nearly zero and the supply current to the electric motor section 22 reaches a minimum value i1.

As the first valve 17 is opened at time t1, the gas in the load-lock chamber 13 under atmospheric pressure is rapidly led into the pump mechanism section 21, thus quickly increasing the pressure load of the vacuum pump 20. Accordingly, the output torque of the electric motor section 22 or the load torque of the vacuum pump 20 rises. That is, the current value increases at time t1 in Fig. 2(b). At this time, the increased speed of the current value or the increased speed of the load torque of the vacuum pump 20 changes upward from zero to a non-zero increased speed. That is, as the current value is constant before time t1, the increased speed of the current value is zero.

The ECU 31 computes the increased speed of the load torque of the vacuum pump 20 from the detected information from the current detector 32. When the ECU 31 determines that the increased speed is greater than a predetermined value, the ECU 31 decides that an abrupt upward change has occurred in the increased speed of the load torque of the vacuum pump 20. Based on the decision, the ECU 31 reduces the rotational speed of the electric motor section 22 to decrease the increased speed of the electric motor section 22 to a predetermined target value, for example, the increased speed of the load torque corresponding to a straight line 61 indicated by the one-dot chain line in Fig. 2(b). In other words, the ECU 31 executes deceleration control on the electric motor section 22.

At this time, the ECU 31 repeatedly executes the deceleration control to gradually reduce the drive frequency in the supply current to the electric motor section 22. The gradual reduction gradually lowers the rotational speed of the electric motor section 22. That is, the drive frequency is gradually reduced from the drive frequency fmax by the ECU 31 starting at time t1.

The reduction in drive frequency lowers the rotational speed of the electric motor section 22. The reduction in rotational speed suppresses the tendency of the pressure load of the vacuum pump 20 to increase. This reduces the increased speed of the load torque of the vacuum pump 20.

The ECU 31 adjusts the drive frequency in such a way that the value of the supply current to the electric motor section 22 does not exceed the upper limit i2. This adjustment is carried out by priority over the deceleration control. That is, when deciding that the current value has reached the upper limit i2, the ECU 31 rapidly reduces the drive frequency of the electric motor section 22 from a drive frequency f1 at that time (time t3 in this embodiment) toward the drive frequency fmin on the lower-speed side.

The reduction in the rotational speed of the electric motor section 22 based on the rapid decrease in drive frequency suppresses the tendency of the output torque of the electric motor section 22 to increase, i.e., the load torque of the vacuum pump 20, so that the torque does not exceed the upper limit corresponding to the upper limit i2. Then, the ECU 31 adjusts the drive frequency to keep as high as possible the rotational speed of the electric motor section 22 to accomplish highly efficient evacuation of the load-lock chamber 13 within the range where the current value does not exceed the upper limit i2.

The upper limit i2 of the current value has been set to prevent the components of the vacuum pump 20 from being damaged by the output torque of the electric motor or the load torque of the vacuum pump 20 from becoming excessively large.

When the pressure load of the vacuum pump 20 decreases due to the depressurization of the load-lock chamber 13 by the

vacuum pump 20, the ECU 31 increases the drive frequency toward the drive frequency fmax to make the rotational speed of the electric motor section 22 as high as possible (between time t4 and time t5) within the range where the current value does not exceed the upper limit i2. At this time, the pressure load of the vacuum pump 20 is decreased although the drive frequency is increased so that the load torque (i.e., the current value) of the vacuum pump 20 shows a tendency to decrease in the embodiment.

This embodiment can provide the following advantages.

(1) The ECU 31 performs deceleration control to decrease the rotational speed of the electric motor section 22 when an increase in load torque of the vacuum pump 20 abruptly changes upward. This can reduce the increased speed at the time the load torque of the vacuum pump 20 rises. It is therefore possible to reduce shocks applied to the components of the vacuum pump 20 when the increased speed of the load torque of the vacuum pump 20 abruptly changes upward or in the state where the increased speed is high and continues after the upward change. This eliminates the need to reinforce the components of the vacuum pump 20 in order to improve the shock resistance, thereby preventing enlargement and weight increase of the vacuum pump 20 that would otherwise be originated from the reinforcement.

(2) The ECU 31 computes the load torque of the vacuum pump 20 based on the value of the supply current to the electric motor section 22. This makes it unnecessary to particularly provide a torque sensor or another device to detect the load torque of the vacuum pump 20. This leads to cost reduction and simplification of the structure.

(3) The ECU 31 repeatedly monitors the increased speed

of the load torque of the vacuum pump 20 at a predetermined time interval and keeps doing the monitoring even after it determines that the increased speed of the load torque of the vacuum pump 20 has abruptly changed upward. Accordingly, the rotational speed of the electric motor section 22 is controlled adequately according to a change in the increased speed of the load torque of the vacuum pump 20 even after the deceleration control has started.

(4) When the increase in load torque of the vacuum pump 20 is greater than a predetermined value, the ECU 31 decides that the increased speed of the vacuum pump 20 has abruptly changed upward and executes the deceleration control. This eliminates a process for computing a difference in the increased speed of the load torque of the vacuum pump 20 as compared with the mode that compares, for example, the increased speed of the load torque of the vacuum pump 20 at a predetermined time and the increased speed at a predetermined time different from the former predetermined time. That is, the arithmetic operation in the ECU 31 is made simpler to reduce the load thereon.

In the time chart in Fig. 2(b), as the pressure load associated with evacuation of the vacuum pump 20 is nearly constant (nearly zero), the value of the increased speed of the load torque of the vacuum pump 20 before time t1 at which the rise of the load torque of the vacuum pump 20 has started becomes a constant value (zero). In such a case, it is possible to accurately determine whether the increased speed of the load torque has abruptly changed upward or not by merely determining whether the increased speed of the load torque is greater than a predetermined value or not. In this case, therefore, it is possible to accurately determine whether the increased speed of the load torque has abruptly changed upward or not without calculating the difference in

increased speed.

(5) The ECU 31 carries out the deceleration control to reduce the increased speed in load torque of the vacuum pump 20 to a predetermined target value. This controls the increased speed of the load torque of the vacuum pump 20 in such a way as to come closer to or seek the predetermined target value. The control can reduce the increased speed at the rising of the load torque of the vacuum pump 20 greater than the increased speed in the prior art.

(6) The ECU 31 controls the electric motor section 22 in such a way that the load torque of the vacuum pump 20 does not exceed a predetermined upper limit or the upper limit of the load torque corresponding to the upper limit i2. Accordingly, the ECU 31 restricts the maximum value of the load torque that acts on the vacuum pump 20, making it possible to prevent deformation, damage or the like of the components of the vacuum pump 20 that originates from an excess load torque.

(7) The deceleration control is performed by the ECU 31 by changing the drive frequency in the supply current to the electric motor section 22 toward the low-speed side of the rotational speed of the electric motor section 22. The change in drive frequency toward the low-speed side reduces the rotational speed of the electric motor section 22, thereby decreasing the pressure load of the vacuum pump 20. The reduction in pressure load lowers the increased speed of the load torque of the vacuum pump 20.

(8) The electric motor section 22 is constructed by a synchronous motor type brushless DC motor. This makes it easier to enhance the durability of the electric motor section 22 as compared with a motor with a brush. Further, the rotational speed of the electric motor section 22 is adjusted

by adjusting the drive frequency in supply current regardless of the load torque that acts on the vacuum pump 20.

(9) The load-lock chamber 13 is the relay point at the time a work item is exchanged between the atmospheric pressure space surrounding the semiconductor production apparatus 11 and the process chamber 12. Therefore, the pressure in the load-lock chamber 13 is frequently increased to atmospheric pressure from a predetermined degree of vacuum. That is, a rapid increase in load torque originating from a sudden increase in pressure load of the vacuum pump 20 that evacuates the load-lock chamber 13 frequently occurs in the vacuum pump 20. It is therefore particularly effective to improve the durability of the vacuum pump 20 by using the inverter 30 that has the motor control means of the embodiment in such a mode.

The invention can also be applied in the following mode without departing from the scope of the present invention.

In the illustrated embodiment, the ECU 31 is constructed in such a way that when the ECU 31 decides that an increased speed in load torque of the vacuum pump 20 is greater than a predetermined value, the ECU 31 determines that the increased speed of the vacuum pump 20 has abruptly changed upward and executes the deceleration control to reduce the rotational speed of the electric motor section 22. Instead of the control, the ECU 31 may compute the rate of change in the increased speed of the load torque of the vacuum pump 20 or the amount of change in increased speed per unit time and may execute the deceleration control when deciding that the computation result is greater than a predetermined value. This modification allows the controller to accurately grasp how much the increased speed of the load torque of the vacuum pump 20 has changed in a predetermined time even when the increased speed of the load torque of the vacuum pump 20

before time t1 is not constant.

In this case, the ECU 31 computes, for example, the difference between the increased speed of the load torque at the current point of time and the increased speed of the load torque at a predetermined time prior to the current time. When the ECU 31 determines that the computation result of subtracting the increased speed of the load torque at a predetermined time prior to the current time from the increased speed of the load torque at the current time, i.e., the difference in the amounts of the increased speed is greater than a predetermined value, the ECU 31 decides that an abrupt upward change has occurred in the increased speed of the load torque of the vacuum pump 20. Having made the decision, the ECU 31 carries out the deceleration control to reduce the increased speed of the load torque of the vacuum pump 20.

The increased speed of the load torque of the vacuum pump 20 need not show a tendency of linear increase over the entire period from the time (time t1) at which the ECU 31 has started reducing the drive frequency to the point at which the current value of the electric motor section 22 reaches the upper limit i2. For example, if the increased speed of the load torque starting at time t1 is made smaller than that in the prior art, the increased speed of the load torque may be made greater than that in the prior art until the current value reaches the upper limit i2 thereafter. This makes the time for the current value to reach the upper limit i2 shorter than in the prior art while reducing the increased speed immediately after a rise in the load torque of the vacuum pump 20 has started.

The ECU 31 may execute the deceleration control to reduce the rate of change in increased speed of the load torque of the vacuum pump 20 (the amount of a change in increased speed

per unit time) toward a predetermined target value. In this case, the predetermined target value is, for example, the rate of change in increased speed of the load torque corresponding to a curve 62 indicated by the one-dot chain line in Fig. 3(b). Fig. 3(a) is a time chart showing the drive frequency in the electric motor section 22 and Fig. 3(b) is a time chart showing the current value in the electric motor section 22. A broken line 91 in Fig. 3(a), like that in Fig. 2(a), indicates the drive frequency of the electric motor in the prior art, and a broken line 92 in Fig. 3(b), like that in Fig. 2(b), indicates the value of the current supplied to the electric motor in the prior art.

According to the modification, the rate of change in increased speed of the load torque of the vacuum pump 20 is controlled in such a way as to come closer or coincide with the predetermined target value. This control makes the increased speed, at least at the time the load torque of the vacuum pump 20 has started rising, smaller than the increased speed in the prior art. Of shocks applied to the components of the vacuum pump 20, therefore, the shock that is originated from the rate of change in increased speed of the load torque of the vacuum pump 20 can be made smaller.

Monitoring the increased speed of the load torque of the vacuum pump 20 by the ECU 31 may be stopped either immediately after the ECU 31 decides that the increased speed has abruptly changed upward or after a predetermined time elapses from the time at which the decision was made. This can reduce the burden on the ECU 31 associated with the monitoring as compared with the case where the ECU 31 continuously and repeatedly executes the monitoring as long as the ECU 31 is in operation.

In this case, the number of times the deceleration

control is repeatedly executed by the ECU 31 may be restricted. This can permit, for example, the rotational speed of the electric motor section 22 to be more quickly returned to a high rotational speed that ensures the high evacuation efficiency of the vacuum pump 20, while making the shock applied to the components of the vacuum pump 20 smaller at the time the load torque of the vacuum pump 20 rises.

If a lower limit is set for the drive frequency of the electric motor section 22 and the electric motor section 22 is driven in such a way that the drive frequency does not go below the lower limit, for example, the number of repetitive executions of the deceleration control should not necessarily be restricted.

At the time of reducing the drive frequency of the electric motor section 22, the drive frequency may be reduced rapidly, not gradually, toward the drive frequency fmin from the drive frequency fmax. Even in this case, it is possible to reduce the increased speed at the time the load torque of the vacuum pump 20 rises.

The upper limit i2 of the supply current to the electric motor section 22 may not be provided. That is, the maximum value of the load torque of the vacuum pump 20 may not be limited.

The load torque of the vacuum pump 20 may be grasped from other means than the value of the supply current to the electric motor section 22 by, for example, providing a torque sensor to detect the load torque of the vacuum pump 20.

The electric motor section 22 may be constituted by a synchronous motor type brushless motor other than a brushless DC motor. Examples of this motor are a reluctance synchronous

motor, a stepping motor, an inductor type synchronous motor, a permanent magnet synchronous motor and a hysteresis synchronous motor. The electric motor section 22 may be constituted by an inductive motor type brushless motor or a brushless motor different from those mentioned above. The electric motor section 22 may also be constituted by a motor with a brush, such as a DC motor or a universal motor.

The electric motor section 22 may be of a type in which rotational speed can be adjusted by adjusting the voltage value of the supply current to the electric motor section 22. In this case, the voltage value is equivalent to a rotational speed instruction value.

Although the vacuum pump 20 is provided for the load-lock chamber 13 in the above-described embodiment, the vacuum pump 20 may be for the process chamber 12. The vacuum pump 20 may be used for other apparatuses than the semiconductor production apparatus 11 as well.

Although the electric motor section 22 is the control target in the embodiment in the case where the first valve 17 is opened from the state where the load-lock chamber 13 is at atmospheric pressure, the present invention is not limited to this particular case. For instance, deceleration control of the electric motor section 22 may be executed to reduce the increased speed of the load torque of the vacuum pump 20 when the electric motor section 22 is activated. In the present invention, the increased speed of the load torque of the vacuum pump 20 is not limited only to the point at which the speed increases from the state of zero, but may include the case where deceleration control of the electric motor section 22 is executed to reduce the increased speed of the load torque even at the time the increased speed becomes greater from a speed higher than zero.